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A Multipurpose Arcade Combat Simulator (MACS)

James E. Schroeder

ARI Field Unit at Fort Benning, Georgia
Training Research Laboratory

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EDGAR M. JOHNSON
Technical Director

L. NEALE COSBY
Colonel, IN
Commander

Technical review by

Douglas J. Bobko
Joel D. Schendel

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The purpose of the present paper is to describe the Multipurpose Arcade Combat
Simulator (MACS) currently being developed by the Army Research Institute, Fort
Benning Field Unit. MACS represents a low-cost training/simulation alternative
which can eventually be adapted to a variety of weapon systems. Currently, the
hardware consists of a microcomputer, disk drives, Pascal language card, joy
sticks, a light pen, and dummy weapons. The light pen has been fitted with
corrective lenses in order that accurate readings can be taken at a range of 10
ft. The light pen currently can be mounted to either a dummy M16A1 rifle or an

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expended M72A2 Light Antitank Weapon (LAW). The system provides immediate visual and auditory feedback of hit/miss shot location. In addition, the system can provide training in traditionally difficult to train areas such as the effects of wind and moving target engagement. Current and planned training software are discussed in detail. Other possible advantages of the MACS system which are addressed in this paper include cost savings, weapon training for components with limited ranges (e.g., ROTC, USAEUR, and Reserve Components), implications for mobilization, and the additional training flexibility provided by the MACS system.

A Multipurpose Arcade
Combat Simulator (MACS)

James E. Schroeder

Submitted by
Seward Smith, Chief
ARI Field Unit at Fort Benning, Georgia

Approved as technically adequate
and submitted for publication by
Harold F. O'Neil, Jr., Director
Training Research Laboratory

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This paper presents a new concept in low-cost, part-task simulator/trainers called the Multipurpose Arcade Combat Simulator (MACS). When compared with other currently available simulator/trainers, it is very low in cost and can be constructed from off-the-shelf components. The system is not dedicated to one weapon. Rather, it is flexible enough to potentially simulate/train several different weapons in addition to running other computer-assisted instruction programs. Because of its low cost and flexibility, the system has great potential for mass-training in the case of mobilization, training in units where live-fire ranges are not available, and training when ammunition is not available or ammunition costs are too high. The present paper describes the MACS system and the software development effort. Other reports on the training effectiveness of the MACS system are forthcoming.

EDGAR M. JOHNSON
Technical Director

A MULTIPURPOSE ARCADE COMBAT SIMULATOR (MACS)

EXECUTIVE SUMMARY

Requirement:

This report describes a low-cost, part-task simulator/trainer named the Multipurpose Arcade Combat Simulator (MACS). This system is currently being developed and tested by the US Army Research Institute, Fort Benning Field Unit.

Procedure:

A number of training programs are described. Currently, MACS software exists for training marksmanship on the M16A1 Rifle and the M72A2 Light Antitank Weapon (LAW). In addition, other software development is planned and descriptions of programs are included in the present paper.

Findings:

The MACS system has the potential of providing low-cost training on a number of different weapons. MACS also offers a strong motivational component when programmed with a point system like an arcade game. In addition, MACS offers marksmanship training enhancements which have been traditionally difficult to provide such as the effects of wind and gravity on the projectile, immediate feedback about hit/miss location, lead rules for moving targets, and diagnosis of steady position, trigger jerk, and other shooting problems.

Utilization of Findings:

Research is currently underway to determine the training effectiveness of the MACS system. If training on the MACS system results in positive transfer to live fire or is positively correlated with live fire, then MACS will be an effective vehicle for training, evaluation, and the prediction of future marksmanship performance. The MACS system offers the advantages of low cost and flexibility. In addition, MACS is especially appropriate for units with no access to live-fire ranges, or in situations where ammunition is unavailable or very expensive.

A MULTIPURPOSE ARCADE COMBAT SIMULATOR (MACS)

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A MULTIPURPOSE ARCADE COMBAT SIMULATOR (MACS)

INTRODUCTION

The proliferation of microcomputers and accompanying software is steadily increasing while corresponding costs are showing substantial reductions. Consequently, the Army is increasing its efforts to capitalize on the high work capabilities offered by the new technology at a relatively low cost. Two application areas with exceptional potential are training and simulation. The purpose of the present paper is to describe and discuss a low-cost training/simulation system being developed by the Army Research Institute, Fort Benning Field Unit. The Multipurpose Arcade Combat Simulator (MACS) system has been configured to be flexible and to fully exploit microcomputer technology.

At the core of the MACS system is a microcomputer, disk drive(s) (for data and program storage), and a monitor, all of which can be purchased off-the-shelf. This basic system can utilize any of the existing software packages which are currently available (e.g., word processing, management aids, decision-making aids, self-improvement programs, data-reduction software, etc.). The basic system could also presumably run any computer-assisted instruction (CAI) software which has been developed or is currently being developed. Also, with the addition of a commercial videodisc player, the system can utilize any CAI/videodisc training programs being developed or already available (e.g., Schroeder, Dyer, Czerny, Gillotti, & Youngling, 1982 and Young & Tosti, 1981).

With the addition of other hardware and software, the system can provide a truly flexible and unique Army training capability. A light pen is an electronic device that reads the raster scan on a monitor and determines the X and Y locations on the monitor signifying where the light pen is pointed. Traditionally, light pens have been used in close physical proximity to the monitor (e.g., a student might use a light pen to select an alternative on a multiple choice question). Such applications are usually made for two reasons: (a) to give the student a simple way of interacting with the computer and (b) to prevent the student from interacting with the computer's keyboard and possibly damaging the hardware or bombing the program. With an additional corrective lens, the light pen can be moved to more distant locations and, when attached to certain weapon systems (e.g., the M16A1 rifle), can provide a tool for relatively low-cost training and simulation. By utilizing high resolution graphics, this relatively simple system can enhance regular training by providing simulated sight pictures, realistic targets and backgrounds, and most important from a training standpoint, precise feedback about hit/miss location. The possible addition of an industrial videodisc player to the system adds the potential for even more realistic training. Also, certain training topics which have traditionally been difficult or impossible might be accomplished with the MACS system (e.g., the effects of wind and gravity, moving target engagement, etc.). Additionally, with creative programming, the training could be structured to create an arcade game atmosphere with: levels of difficulty; a point system; realistic targets and background; and various field situations leading up to and including an actual combat defense scenario similar to that provided by IRETS (Infantry Remoted Engagement Target System), for live fire.

Finally, the proposed system could be multipurpose (in addition to the flexibility discussed earlier), because the light pen could conceivably be attached to and "fired from" a number of potential weapon systems besides the M16A1 rifle (see Table 1 for a list of potential weapons). It must be emphasized that the weapons listed in Table 1 represent only a potential list. For each weapon listed, further investigation is needed to determine whether the MACS system is appropriate. Although the purpose of the present paper is to present the MACS concept, a certain amount of development has been done by the present author. This work has been preliminary and exploritory for the most part. At the present time, no data have been collected to determine the system's actual training capabilities, although such research is planned. In the next section of this paper, the current hardware configuration is presented. In the third section of this paper, the software that has been completed along with software currently under development will be described. In the final section, some possible implications of the MACS training/simulation system for Army training will be discussed.

CURRENT MACS HARDWARE

Currently, the MACS hardware is configured with an Apple II+ microcomputer with two disk drives, a Sony monitor, a Symtec light pen that has been modified with corrective lenses so that it can accurately read the monitor at 10 ft., an Apple Language Card with Pascal language software, and a deactivated "dummy" M16A1 rifle. Also, an expended M72A2 Light Antitank Weapon (LAW) has been modified to be used with the system. For both the M16A1 rifle and the LAW, electronic switches have been wired to the trigger mechanisms (see Figure 1).

The above hardware was selected primarily because it was available. Currently, other manufacturers and configurations are being considered. The primary consideration for the microcomputer will be dependability, low cost, graphics capability, and quality of the graphics. The primary considerations for the light pen are reliability, low cost, and accuracy. Resolution and low cost are the main considerations for the monitor.

CURRENT AND FUTURE SOFTWARE

The software developed to date addresses two different weapons: the M16A1 rifle and the M72A2 LAW. For both applications, small training programs have been consolidated into large programs which provide the student access to any desired scenarios. When a large program is executed, the first thing the student must do is zero the weapon. If the system is primed for the M16A1 rifle, the student zeros the weapon by firing five rounds at the center of mass on an "E" type silhouette target (see Osborne, Schroeder, & Heller, 1980), that has been scaled to appear to be 100 m when the shooter is 3 m from the monitor. If the system is programmed for the LAW, the student zeros by firing five rounds at the center of mass of a tank target which has been scaled to appear to be 175 m when the student is 3 m from the monitor. In either case, the student is not shown the location of the hits or misses until after the five rounds have been fired. The reason for witholding feedback about shot location is that the student might practice hold-off, and hence, defeat the purpose of the zeroing procedure. During the zeroing procedure, the computer determines the average X and Y locations for the five shots and then places the center of that shot group

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Table 1

Other Potential MACS Applications

M60 Machinegun

M249 Squad Automatic Weapon (SAW)

.50 Caliber Machinegun

Bradley Infantry Fighting Vehicle M231 Firing Port Weapon

M203 Grenade Launcher

M202A1 Incendiary Rocket Launcher (FLASH)

Dragon

M72A2 Light Antitank Weapon (LAW)
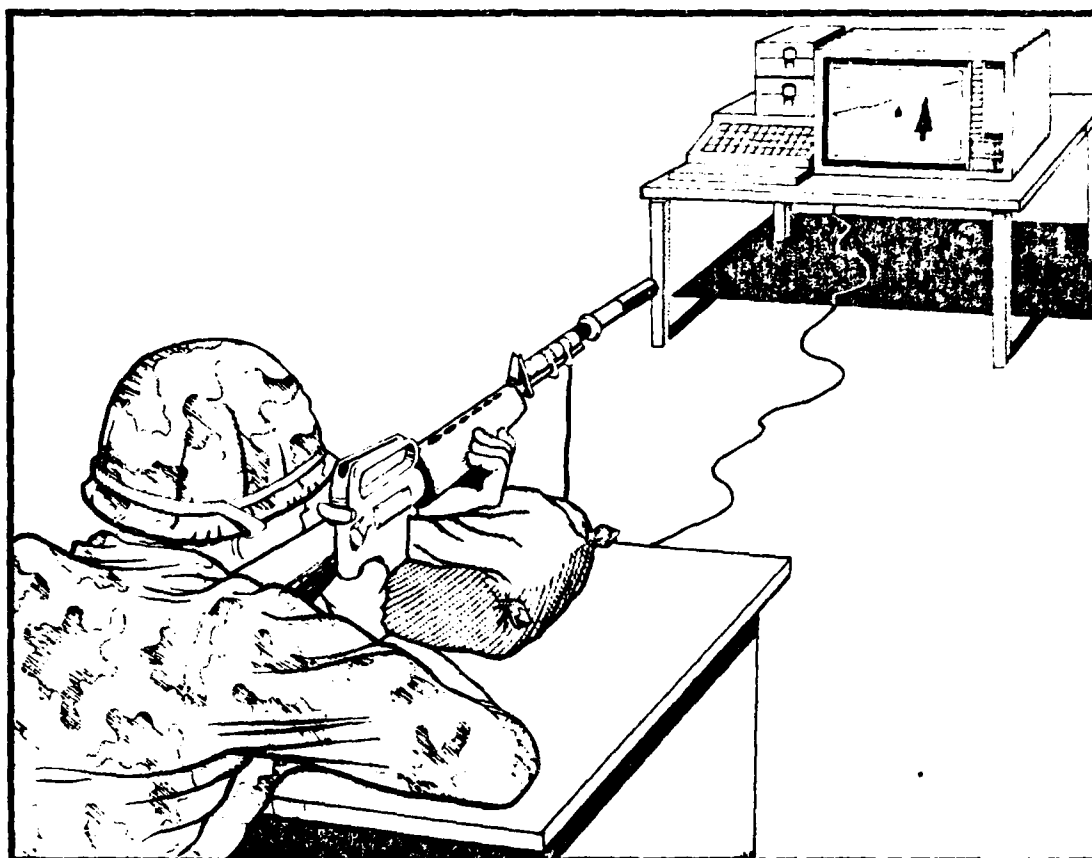
TOW

Pistol

Mortar

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Figure 1. Hardware configuration for the MACS system consisting of microcomputer and disk drives, TV monitor, dummy weapon, and long distance light pen.

on the center of mass for the actual target (i.e., the computer automatically
zeros the weapon for the shooter). The reason that the computer zeros the
weapon is because of some of the hardware features of the system. The light
pen's readin are affected by a number of variables (i.e., four different
adjustments on the light pen, distance from the monitor, the color, brightness,
sharpness, and tint settings on the monitor, and possibly other variables such
as ambient light etc.) Because of all of these possible influences on the
system, it would be very difficult to calibrate the system to one "standard"
setting. A more functional approach is to let those variables vary as they
might between training sessions, make the system calibrate itself at the
beginning of each training period, and then keep those variables constant during
the training. This is exactly what the computerized zeroing procedure
accomplishes. After the five rounds have been fired, the shot group is then
displayed so that the soldier and/or trainer can assess whether or not the shot
group is tight enough (the computer can also assess whether the grouping is
adequate). Following a 15-sec exposure to the shot group, the target and
background disappear and the student is presented with a menu from which he can
select the desired training scenario. In the following two sections, the
current and planned software for the M16A1 rifle and the LAW are discussed.

M16A1 Rifle Software

One program was designed to simulate a field-fire setting. If the student
chooses this program, the first option he has is how many rounds he wants to
shoot at each target. Currently, the soldier enters this number by using the
computer's keyboard. After this decision has been made and entered into the
computer, the target background is painted on the screen. This currently
consists of a hilly green landscape with blue sky and one tree. Next, a scaled
"E" type silhouette target pops up at any reasonable position on the screen.
The exact location is either predetermined by the programmer or else, can be
randomly assigned by the software. There are currently four such scaled targets
which represent distances of 75-300 m when viewed at a distance of 3 m from the
scene. However, these four targets could be changed or other targets added so
that any reasonable distance could be simulated. After the student aims and
squeezes the trigger, four events occur. First, the computer simulates the
sound of a weapon being fired. Next, the computer places a white dot on the
screen in order to provide immediate feedback about hit or miss shot location.
Also, the computer calculates and displays a score for that shot. The score is
a maximum of 50 points if the student hits exact center of mass. The score is
reduced proportionally to the amount of error measured in radial distance from
the center of mass in pixels. The word "pixel" stands for picture element and
represents one unit or point on the screen. The number of pixels varies from
system to system depending on the resolution of the graphics available on that
system. For example, in the Apple II+ high resolution mode there are 192 by 280
pixels representing a total of 53,760 pixels per screen. After computing the
score for a given shot, the system then adds that score to a composite score.
In addition, if the shot location is within three pixels of center of mass, the
computer beeps once. If the shot is two pixels from center of mass, the
computer beeps twice; one pixel, three times, and exact center of mass, four
times. Thus, the student gets both visual and (if he is accurate enough),
auditory feedback. The white dots remain after each shot until the shooter has
fired the appropriate number of shots at that target. After the last shot at a

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given target, the target remains for 15 sec so that the student can examine his shot group. Then, the next target is painted, and the cycle is repeated until the entire scenario is completed. At the end of the entire scenario, the student is shown his total score for the entire scenario along with the percent of all points possible. Finally, he is taken back to the program menu.

A second program is very similar to the one described above, except that another feature has been added. It has always been difficult to teach how to shoot under various wind conditions because of the impossibility of controlling that variable on an actual range. As a result, basic marksmanship training tends to downplay or ignore the effects of wind on the projectile. In this MACS program, the direction and magnitude of the wind is cued to the trainee by the direction and angle of a flag on a distant hill. Having estimated the direction and velocity of the wind, the trainee must then practice hold-off to hit the target. After firing, the screen displays where the bullet would have hit given that range and wind condition. The computer has been programmed to simulate the actual effects of the wind at a given range. Currently, four wind velocities have been included ranging from 0 to 25 miles per hour. Additional software is planned that will show the ideal sight picture on the screen (using graphics) for all wind/distance combinations. In this situation, the trainee would not shoot the weapon, but rather would study the screen. This program could be introduced prior to the actual shooting program, and/or could be introduced for remediation given poor performance on the actual wind program.

A third program deals with moving targets. The trainee sees an "E" type silhouette target moving across the screen from either left to right or right to left. The speed of the target can be randomly changed or kept constant. In order to score points, the trainee must apply the proper lead rule, given the distance and speed. Currently, more realistic, animated personnel targets are being developed to replace the "E" type silhouette targets.

A fourth program also involves moving targets which move much more slowly. The unique feature of this program is that after firing at a target and getting immediate feedback, the last shot is replayed. That is, the target re-emerges at the same place and moves at the same speed. In addition, white dots appear indicating where the trainee had been aiming at each moment before the weapon was fired. In this manner the student, or the trainer, can assess steady position, proper lead, proper tracking, etc. The target stops at the point where the rifle was fired, and a flashing white dot shows the location of the actual shot.

A fifth program was designed to help trainers diagnose shooting problems. In this program, two identical targets are presented on the screen, one about 5 cm directly below the other. The trainee is instructed to shoot at the top target. While aiming at the top target, a flashing white dot on the lower target shows the trainer where the trainee is aiming. This flashing white dot cannot be detected by the trainee if he is aiming properly. In this manner, the trainer potentially can diagnose problems such as steady position, point of aim, and trigger jerk. Although not in the present program, a replay similar to the one mentioned above will eventually be incorporated into this program.

A sixth program is similar to the trainer feedback program described in the preceeding paragraph, except that it allows the trainee to get immediate point of aim feedback without the presence of a trainer. This was accomplished by programming the computer to give momentary auditory beeps, the frequency of which indicates how close to center of mass the rifle is being aimed--the higher the pitch, the closer to center of mass. In this manner, the trainee can shape his own aiming behavior to maximize learning.

Additional software for the M16A1 rifle is planned. One program is designed to help diagnose marksmanship problems. This will be done by having the computer analyze pre-shot light pen coordinates. Hopefully, pre-shot analysis of trends and patterns can help determine which, if any, of the four fundamentals of basic marksmanship (see Osborne, 1982) are being violated. This information could then either be presented to the trainee or the trainer in the form of text on the screen or could be used in a self-paced mode to branch the trainee to another program designed to provide remediation for that particular fundamental.

Another program is designed to give the trainee practice mechanically zeroing his weapon. In this program, the trainee will first fire a three-round shot group. No immediate feedback will be given after each shot. After the three-round shot group has been fired, the target will be enlarged to show the shots' locations on the standard zeroing target (see Smith, Thompson, Evans, Osborne, Maxey, & Morey, 1980). The relative location of each shot will remain the same as actually fired, but the center of the distribution will be randomly misplaced by the computer, i.e., the shot group will be forced off of the center of mass to a new location, indicating a poor zero for the weapon. The trainee's job is to make the mechanical adjustment indicated by the shot-group location. Finally, the trainee fires a second three-round shot group. The computer then displays the new shot group and analyzes whether additional adjustments need to be made. If so, additional training is provided until the trainee is zeroed.

Finally, an arcade game scenario is planned which will provide a defense scenario against an attacking opposing force. This program, perhaps more than the others described above, is being designed to provide "entertrainment". Besides providing an entertaining environment, realistic features will hopefully provide valuable training. In this program, both stationary and moving targets will be presented. The trainee will have to learn to prioritize his shots in order to maximize his score and minimize the score of the opposing force. The trainee gets points by accurate shooting. The opposing force gets points either through the poor marksmanship of the trainee or through the tactical errors of the trainee. For example, if the trainee fires at a distant target while a potentially more dangerous close target is ignored, then the opposing force's score increases. This scenario will approximate the training provided with live fire on the Infantry Remoted Engagement Target System (IRETS) range (except that in IRETS there is no opposing force score built in). For this reason, it will be tested as an inexpensive training alternative to prepare trainees for the IRETS test range.

M72A2 LAW Software

The software that has already been developed for the LAW includes two programs, one for stationary tank targets and one for moving tank targets.

The scenarios presented in both scenarios are analogous to those used in the M16A1 rifle scenarios described above, except that: (a) the light pen is attached to the LAW, (b) instead of a white dot indicating the location of the hit, an explosion is simulated with flame and smoke, (c) tanks are the targets, and (d) time-of-flight delays from firing to impact are simulated. In addition, any of the above training programs designed for the M16A1 rifle could probably be adapted for the LAW.

DISCUSSION

Although the hardware for MACS has been configured and a number of programs have already been developed, the project is really still at the concept level. Much work remains to be done. Various hardware configurations must be considered. Research and testing must be conducted to determine the answer to the obvious question: "Can the MACS system really train?"

The question as to whether or not the MACS system can train marksmanship skills will be answered with empirical data gathered through research efforts at the Army Research Institute, Fort Benning Field Unit. A number of studies and experiments are planned. One of the first studies (currently under way) will correlate scores on MACS with scores on the Weaponeer. The Weaponeer is an existing M16A1 rifle marksmanship trainer/simulator that provides a high level of simulation including realistic recoil and sound (for more information on the Weaponeer, see Spartanics, Ltd., 1976 or Stair, Cobb, Palmer, Bishop, Holcombe, Widby, & Shanahan, 1977). The Weaponeer has been acclaimed to be a very valuable training device, and it probably provides a higher level of realism than the MACS system. However, the cost of the Weaponeer will probably prevent wide distribution throughout the Army.

Another experiment planned will directly compare training on the MACS with conventional training with live fire. After equal time exposure to each, two groups of trainees will be given the same live-fire test. Another potential use of the system would be to place it in the company training areas of either active units or training units. If the software developed is compelling enough, soldiers may voluntarily practice their marksmanship skills. The MACS software may not be as entertaining as Pac-Man, but if it's the only game in town... If not voluntarily used, the training NCO's could be placed in charge of the equipment to use at their discretion (especially on those shooters who need additional training). To test these possibilities, MACS systems will be placed in randomly selected company areas at the Infantry Training Center prior to and while the trainees are receiving Basic Rifle Marksmanship. These companies will then be compared with other similar companies which did not have MACS to supplement regular training. Presumably, MACS software developed for other weapon systems will receive similar testing.

In conclusion, the MACS system offers the opportunity to provide a flexible training/simulation capability at a cost considerably lower than other available options. Also, if successful, the MACS system could be a partial answer to a number of weapon-training problems: the soaring costs of live ammunition, the unavailability of appropriate ranges in some situations (e.g., USAEUR, ROTC, and Reserve Components), weapon training in the case of rapid mobilization, shortages of well-trained instructors, and the high cost of trainer/simulator systems which are dedicated to only one weapon system.

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